TITLE OF THE INVENTION

Displacement Varying Structure of Variable Displacement Compressor

BACKGROUND OF THE INVENTION

The present invention relates to a displacement varying structure of a variable displacement compressor. A typical variable displacement compressor is installed in a refrigerant circuit of a vehicle air conditioning system and changes the displacement based on the pressure in a crank chamber. A displacement varying structure controls the pressure in the crank chamber of the variable displacement compressor.

Some variable displacement compressor have a control valve called pressure sensing valve (for example, refer to Japanese Laid-Open Patent Publication No. 2001-173556).

As shown in Fig. 6, a supply passage 113 connects a crank chamber 111 with a discharge chamber 112 of a variable displacement compressor. A valve chamber 102, which forms part of the supply passage 113, is defined in a housing 101 of the control valve. The valve chamber 102 is connected to the crank chamber 111 by a downstream section of the supply passage 113. The valve chamber 102 accommodates a valve body portion 103a of a rod 103. The valve body portion 103a can be displaced in the valve chamber 102. In accordance with its position in the valve chamber 102, the valve body portion 103a adjusts the opening degree of the supply passage 113.

A pressure sensing chamber 104 is defined in the valve housing 101. A pressure sensing member 105, which is a bellows, is located in the pressure sensing chamber 104. The pressure sensing member 105 divides the interior of the

pressure sensing chamber 104 into a first chamber 104a and a second chamber 104b.

A separation wall 106 is provided in the valve housing 101. The separation wall 106 separates the second chamber 104b from the valve chamber 102. A through hole 107 is formed in the separation wall 106. The through hole 107 extends between the valve chamber 102 and the second chamber 104b. The rod 103 extends through the through hole 107 and is coupled to the pressure sensing member 105.

The rod 103 has a separation portion 103b that is provided at the end adjacent to the pressure sensing chamber 104. The separation portion 103b disconnects the valve chamber 102 from the second chamber 104b. The rod 103 also has a coupler portion 103c, that couples the separation portion 103b with the valve body portion 103a. The diameter of the coupler portion 103c is less than the diameter of the through hole 107. Therefore, this section of the through hole 107 functions as a valve hole 107a that forms part of the supply passage 113.

A fixed restrictor 114 is in the refrigerant circuit. Specifically, the fixed restrictor 114 is located in a discharge pressure zone. The first chamber 104a of the control valve is connected to the discharge pressure zone at a position upstream of the fixed restrictor 114. The second chamber 104b of the control valve is connected to the discharge pressure zone at a position downstream of the fixed restrictor 114. The pressure difference between a section upstream of the fixed restrictor 114 and a section downstream of the fixed restrictor 114 represents the flow rate of refrigerant in the refrigerant circuit. Therefore, the pressure sensing member 105 is displaced according to changes of the refrigerant flow rate in the refrigerant circuit. The

position of the rod 103 (the valve body portion 103a) is determined such that the displacement of the variable displacement compressor is changed to cancel the changes in the refrigerant flow rate.

However, the valve hole 107a of the control valve is connected to the discharge pressure zone (discharge chamber 112) of the refrigerant circuit at a position upstream of the fixed restrictor 114 through an upstream section of the supply passage 113. That is, the valve hole 107a is connected to a section of the discharge pressure zone that is the same as the first chamber 104a and different from the second chamber 104b.

Therefore, the pressures in the valve hole 107a and the second chamber 104b, which are adjacent to each other with the separation portion 103b of the rod 103 in between, are different. This pressure difference can cause foreign particles to enter the sliding sections of the through hole 107 and the rod 103 (the separation portion 103b). Foreign particles between the through hole 107 and the rod 103 can cause the rod 103 to malfunction.

To eliminate such a drawback, Japanese Laid-Open Patent Publication No. 2001-173556 discloses another structure shown in Fig. 7 that is different from the structure shown in Fig. 6. In the control valve shown in Fig. 7, the rod 103 has no structure corresponding to the separation portion 103b. Further, the second chamber 104b is used as part of the supply passage 113. The space between the through hole 107 and the rod 103 (the coupler portion 103c) functions as part of the supply passage 113 and is always open to the second chamber 104b. However, in this case, at the instant at which the valve body portion 103a is displaced to change the valve opening degree, the pressure in the second chamber 104b is directly influenced by the change in the valve opening degree

and is changed. This prevents the pressure sensing member 105 from accurately determining the position of the valve body portion 103a, which adversely affects the control of the displacement.

Particularly, the compressor shown in Fig. 7 is a "variable target pressure difference" type, in which position of the rod 103 (the valve body portion 103a) is determined by the equilibrium of the force of the pressure sensing member 105 and electromagnetic force of an electromagnetic actuator (not shown). This worsens the controllability of the displacement of the compressor shown in fig 7. Specifically, the electromagnetic force of the electromagnetic actuator is sometimes changed abruptly by an excessive degree. In such a case, the valve body portion 103a is displaced abruptly by an excessive degree. This creates a sudden and excessive change in the pressure in the second chamber 104b.

SUMMARY OF THE INVENTION

Accordingly, it is an objective of the present invention to provide a displacement varying structure of a variable displacement compressor, which structure prevents a rod from malfunctioning and the controllability of the displacement from deteriorating.

To achieve the above objective, the present invention provides a displacement varying structure of a variable displacement compressor. The compressor is installed in a refrigerant circuit. The refrigerant circuit has a discharge pressure zone and a suction pressure zone. The variable displacement compressor has a crank chamber The displacement varying structure is capable of varying a displacement of the variable displacement compressor by changing a pressure of the crank chamber. The displacement varying structure includes a

supply passage for connecting the crank chamber with the discharge pressure zone. A bleed passage connects the crank chamber with the suction pressure zone. A control valve is located in a control passage. The control passage is one of the supply passage and the bleed passage. The control valve includes a valve housing defining a valve chamber, a valve hole, and a pressure sensing chamber. The valve chamber and the valve hole form a part of the control passage. A valve body is accommodated in the valve chamber. The valve body is capable of being displaced. The valve body adjusts an opening degree of the valve hole in accordance with the position of the valve body in the valve chamber. A pressure sensing member is accommodated in the pressure sensing chamber. The pressure sensing member divides the pressure sensing chamber into a first chamber and a second chamber. The pressure sensing member is capable of being displaced in accordance with a pressure difference between the first chamber and the second chamber. A separation wall separates in the valve housing the valve chamber and the pressure sensing chamber from each other. The separation wall has a through hole for connecting the valve chamber and the second chamber with each other. A rod extends through the through hole and connects the pressure sensing member and the vale body with each other. The rod has a separation portion that blocks connection between the valve chamber and the second chamber through the through hole. An adjacent zone is adjacent to the second chamber with the separation portion in between. If a part of the through hole that is closer to the valve chamber than the separation portion and opens to the valve chamber forms the valve hole, the valve hole is the adjacent zone. If the valve hole is located at the opposite side of the valve chamber with respect to the second chamber, the valve chamber is the adjacent zone. The adjacent zone and the second chamber are connected to a common pressure zone in the refrigerant circuit.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a cross-sectional view illustrating a swash plate type variable displacement compressor according to one embodiment of the present invention;

Fig. 2 is a cross-sectional view illustrating the control valve installed in the compressor shown in Fig. 1;

Fig. 3 is a partial cross-sectional view illustrating a control valve according to a second embodiment of the present invention;

Fig. 4 is a partial cross-sectional view illustrating a control valve according to a third embodiment of the present invention;

Fig. 5 is a cross-sectional view illustrating a control valve according to a fourth embodiment of the present invention;

Fig. 6 is a partial cross-sectional view illustrating a prior art control valve; and

Fig. 7 is a partial cross-sectional view illustrating another prior art control valve.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First to fourth embodiments of a displacement control

structure used in a variable displacement swash plate type compressor C will now be described. The compressor is installed in a refrigerant circuit of a vehicle air conditioner. In the second to fourth embodiments, only the parts different from the first embodiment are explained. Like members are given the like numbers and detailed explanations are omitted. The first embodiment will now be described.

(Variable Displacement Swash Plate Type Compressor)

As shown in Fig. 1, the compressor C has a housing. The compressor housing includes a cylinder block 11, a front housing member 12, a valve assembly 13, and a rear housing member 14. The front housing member 12 is secured to the front end (left end as viewed in Fig. 1) of the cylinder block 11. The rear housing member 14 is secured to the rear end (right end as viewed in Fig. 1) of the cylinder block 11 with the valve assembly 13 in between.

The cylinder block 11 and the front housing member 12 define a crank chamber 15 in between. A drive shaft 16 is rotatably supported in the crank chamber 15. The drive shaft 16 is coupled to a vehicle engine E, which functions as an external drive source. A lug plate 17 is coupled to the drive shaft 16 and is located in the crank chamber 15. The lug plate 17 rotates integrally with the drive shaft 16.

A cam plate, which is a swash plate 18 in the first embodiment, is housed in the crank chamber 15. The swash plate 18 slides along and inclines with respect to the drive shaft 16. A hinge mechanism 19 is located between the lug plate 17 and the swash plate 18. The hinge mechanism 19 causes the swash plate 18 rotate integrally with the lug plate 17 and the drive shaft 16, and permits the swash plate 18 to incline with respect to the drive shaft 16, while sliding on the drive shaft 16 along the axis of the drive shaft 16. The

inclination angle of the swash plate 18 is represented by an angle formed by the swash plate 18 and a plane perpendicular to the axis of the drive shaft 16.

Cylinder bores 11a (only one is shown in the drawing) are formed in the cylinder block 11 to surround the drive shaft 16. Each cylinder bore 11a extends through the cylinder block 11 along the axis of the drive shaft 16. A single headed piston 20 is accommodated in each cylinder bore 11a. The piston 20 reciprocates inside the cylinder bore 11a. The openings of each cylinder bore 11a are closed by the valve assembly 13 and the corresponding piston 20. A compression chamber 21 is defined inside each cylinder bore 11a. The volume of each compression chamber 21 changes as the corresponding piston 20 reciprocates. Each piston 20 is coupled to the peripheral portion of the swash plate 18 by a pair of shoes 22. The shoes 22 convert rotation of the swash plate 18, which rotates with the drive shaft 16, to reciprocation of the pistons 20.

A suction chamber 23 and a discharge chamber 24 are defined between the valve assembly 13 and the rear housing member 14. The valve assembly 13 has suction ports 25, suction valve flaps 26, discharge ports 27, and discharge valve flaps 28. Each suction port 25, each suction valve flap 26, each discharge port 27, and each discharge valve flap 28 correspond to one of the cylinder bores 11a. As each piston 20 moves from the top dead center to the bottom dead center, refrigerant gas in the suction chamber 23 is drawn into the corresponding compression chamber 21 through the corresponding suction port 25 while flexing the suction valve flap 26 to an open position. Refrigerant gas that is drawn into the compression chamber 21 is compressed to a predetermined pressure as the piston 20 is moved from the bottom dead center to the top dead center. Then, the gas is discharged to the

discharge chamber 24 through the corresponding discharge port 27 while flexing the discharge valve flap 28 to an open position.

(Displacement varying structure)

The pressure of the crank chamber 15 contributes to control of the inclination angle of the swash plate 18 and is controlled by a displacement varying structure. The displacement varying structure includes a bleed passage 29, a supply passage 30, and a control valve CV1, which are provided in the compressor housing shown in Fig. 1. The bleed passage 29 connects the crank chamber 15 with the suction chamber 23, which forms part of a suction pressure zone of the refrigerant circuit. The supply passage 30 connects a discharge pressure zone Pd of the refrigerant circuit with the crank chamber 15. The supply passage 30 is regulated by the control valve CV1. The control valve CV1 is inserted in and fixed to an accommodation recess 35 formed in the rear housing member 14.

Adjusting the opening degree of the control valve CV1 controls the ratio between the flow rate of highly pressurized gas supplied to the crank chamber 15 from the discharge pressure zone Pd through the supply passage 30 and the flow rate of refrigerant gas conducted from the crank chamber 15 to the suction chamber 23 through the bleed passage 29. The pressure of the crank chamber 15 is determined, accordingly. The difference between the pressure in the crank chamber 15 and the pressure in the compression chambers 21 with the pistons 20 in between is changed according to changes in the pressure of the crank chamber 15. This alters the inclination angle of the swash plate 18. As a result, the stroke of each piston 20, that is, the displacement of the compressor C, is controlled.

(Refrigerant Circuit)

As shown in Fig. 1, the refrigerant circuit of the vehicle air conditioner includes the compressor C and an external refrigerant circuit G. The external refrigerant circuit G includes a condenser (gas cooler) 31, an expansion valve 32, and an evaporator 33. A section of the refrigerant circuit from the discharge chamber 24 to the inlet of the condenser 31 form the discharge pressure zone Pd.

A fixed restrictor 34 is provided in the discharge pressure zone Pd. As the flow rate of refrigerant in the refrigerant circuit increases, the pressure difference between a section upstream of the fixed restrictor 34 and a section downstream of the fixed restrictor 34 is increased. This pressure difference will be referred to as a two-point pressure difference. That is, the two-point pressure difference corresponds to the pressure loss between the section upstream of the fixed restrictor 34 and the section downstream of the fixed restrictor 34, and positively correlates with the flow rate in the refrigerant circuit. Therefore, detecting the two-point pressure difference permits the flow rate of the refrigerant circuit to be indirectly detected.

The discharge pressure zone Pd of the refrigerant circuit includes a first pressure zone PdH and a second pressure zone PdL. The first pressure zone PdH is located upstream of the fixed restrictor 34, or at the side corresponding to the discharge chamber 24. The second pressure zone PdL is located downstream of the fixed restrictor 34, or at the side corresponding to the condenser 31. The pressure of the first pressure zone PdH is higher than the pressure of the second pressure zone PdL. The pressure of the first pressure zone PdH and the pressure of the second pressure zone PdL are each introduced to the control valve CV1. The supply passage 30 includes an upstream section 30a upstream of the accommodation

recess 35 and a downstream section 30b downstream of the accommodation recess 35. The upstream section 30a is connected to the second pressure zone PdL.

(Control Valve)

As shown in Fig. 2, the control valve CV1 includes an inlet valve portion and a solenoid 60. The inlet valve portion is arranged in an upper portion of the valve CV1, while the solenoid 60 is arranged in a lower portion of the valve CV1. The inlet valve portion adjusts the opening degree (throttle amount) of the supply passage 30. The solenoid 60 is an electromagnetic actuator for urging a rod 40 located in the control valve CV1 based on a current supplied from an outside source. The rod 40 includes a separation portion 41, a coupler portion 42, a valve body portion 43, and a guide portion 44. The separation portion 41 is at the distal end of the rod 40. The diameter of the coupler portion 42 is less than that of the separation portion 41. The valve body portion 43 is located at a middle portion of the rod 40. The guide portion 44 is located at the proximal end of the rod 40. The valve body portion 43 forms part of the guide portion 44.

The control valve CV1 has a valve housing 45. The housing 45 includes a plug 45a and an upper portion 45b and a lower portion 45c. The upper portion 45b defines the shape of the inlet valve portion. The lower portion 45c defines the shape of the solenoid 60. A valve chamber 46 is defined in the upper portion 45b of the valve housing 45. A pressure sensing chamber 48 is defined between the upper portion 45b and the plug 45a, which is press fitted to the top portion of the upper portion 45b. The upper portion 45b includes a separation wall 49 located between the valve chamber 46 and the pressure sensing chamber 48. A through hole 47 is formed in the separation wall 49. The through hole 47 extends between the valve chamber 46 and the pressure sensing chamber

48.

The rod 40 extends through the valve chamber 46 and the through hole 47. The rod 40 moves in the axial direction of the control valve CV1, or in the vertical direction as viewed in Fig. 2. The separation portion 41 of the rod 40 is slidably inserted in the through hole 47 and separates the through hole 47 from the pressure sensing chamber 48. The diameter of the coupler portion 42 of the rod 40 is less than that of the through hole 47 and permits the valve chamber 46 to communicate with the through hole 47.

A space 50 is defined between an outer surface 45d of the upper portion 45b and an inner surface 35a of the accommodation recess 35 of the rear housing member 14. The space 50 is divided into a first connecting chamber 50a and a second connecting chamber 50b by a first seal member 68 provided about the upper portion 45b. The second connecting chamber 50b is closer to the opening of the accommodation recess 35 than the first connecting chamber 50a. That is, the second connecting chamber 50b is located below the first connecting chamber 50a as viewed in Fig. 2. The second connecting chamber 50b is disconnected from the outside air by a second seal member 69 provided about the lower portion 45c.

The bottom of the valve chamber 46 is formed by the upper surface of a fixed iron core 62. A radially extending first port 51 is formed in the wall surrounding the valve chamber 46 of the upper portion 45b. The first port 51 connects the second connecting chamber 50b with the valve chamber 46. Therefore, the valve chamber 46 is connected to the crank chamber 15 through the first port 51, the second connecting chamber 50b, and the downstream section 30b of the supply passage 30.

A radially extending second port 52 is formed in the separation wall 49 surrounding the through hole 47 of the upper portion 45b. The second port 52 connects the first connecting chamber 50a with a portion 47a of the through hole 47 that is close to the valve chamber 46. Therefore, the portion 47a of the through hole 47 closer to the valve chamber 46 is connected to the second pressure zone PdL through the second port 52, the first connecting chamber 50a, and the upstream section 30a of the supply passage 30.

That is, the first port 51, the valve chamber 46, the through hole 47, and the second port 52 function as an internal passage of the control valve CV1 and as part of the supply passage 30 connecting the second pressure zone PdL and the crank chamber 15.

The valve body portion 43 of the rod 40 is located in the valve chamber 46. A step defined between the valve chamber 46 and the through hole 47 forms a valve seat 53. A portion 47a of the through hole 47 adjacent to the valve chamber 46 functions as a valve hole. The rod 40 shown in Fig. 2 is located at the lowermost position. When the rod 40 is moved from the lowermost position to the uppermost position, where the valve body portion 43 contacts the valve seat 53, the valve hole 47a is closed. The valve body portion 43 of the rod 40 is an inlet valve body that controls the opening degree of the supply passage 30.

A pressure sensing member 54, which is a bellows, is located in the pressure sensing chamber 48. The upper end of the pressure sensing member 54 is fixed to the plug 45a of the valve housing 45. The pressure sensing member 54 is shaped as a cylinder with a closed end. The pressure sensing member 54

divides the pressure sensing chamber 48 into a first chamber 55, which is the interior of the pressure sensing member 54, and a second chamber 56, which is the exterior of the pressure sensing member 54. The second chamber 56 is located closer to the valve chamber 46 compared to the first chamber 55 and is connected to the valve chamber 46 by the through hole 47. The second chamber 56 is adjacent to the valve hole 47a with the separation portion 41 of the rod 40 in between. The lower end of the pressure sensing member 54 is displaced in accordance with the pressure difference between the first chamber 55 and the second chamber 56. A recess is formed at the lower end of the pressure sensing member 54. The recess functions as a rod receiving portion 54a. The separation portion 41 of the rod 40 is inserted in and press fitted to the rod receiving portion 54a.

The first chamber 55 is connected to the discharge chamber 24 through a third port 57 formed in the plug 45a, and a pressure introduction passage 37 formed in the rear housing member 14. The discharge chamber 24 forms a part of the first pressure zone PdH. A fourth port 58 is formed in a circumferential wall of the upper portion 45b of the valve housing 45 that surrounds the first chamber 55. The second chamber 56 is connected to the second pressure zone PdL through the fourth port 58, the first connecting chamber 50a, and the upstream section 30a of the supply passage 30. Therefore, the pressure difference between the first chamber 55 and the second chamber 56 is equal to the two-point pressure difference in the refrigerant circuit, which is the pressure difference between the first pressure zone PdH and the second pressure zone PdL.

The first connecting chamber 50a connects the second port 52 with the fourth port 58. That is, the passage from the second pressure zone PdL to the control valve CV1 branches at

the first connecting chamber 50a. The branched portions are connected to the second chamber 56 and the valve hole 47a. In other words, part of the passage connecting the second chamber 56 to the second pressure zone PdL and part of the passage connecting the valve hole 47a to the second pressure zone PdL both include the upstream section 30a of the supply passage 30 and the first connecting chamber 50a.

That is, if one of the valve hole 47a and the valve chamber 46 that is adjacent to the second chamber 56 with the separation portion 41 in between is defined as an adjacent zone, the adjacent zone is the valve hole 47a in this embodiment. The second chamber 56 and the valve hole 47a are both connected to a common pressure zone in the refrigerant circuit, or to the second pressure zone PdL.

The solenoid 60 includes an accommodation cylinder 61 that has a closed end. The fixed iron core 62 is fitted to the upper portion of the accommodation cylinder 61. Accordingly, a solenoid chamber 63 is defined in a lower portion of the accommodation cylinder 61. A movable iron core 64 is located in the solenoid chamber 63. The movable iron core 64 is movable along the axial direction of the control valve CV1. A guide hole 62a is formed in the center of the fixed iron core 62. The guide hole 62a extends along the axial direction of the control valve CV1. The guide portion 44 of the rod 40 is received by the guide hole 62a. The guide portion 44 is movable in the axial direction of the control valve CV1. The lower end of the guide portion 44 abuts against the movable iron core 64 in the solenoid chamber 63.

A valve body urging spring 66 is accommodated in the solenoid chamber 63. The valve body urging spring 66 urges the movable iron core 64 toward the fixed iron core 62, thereby urging the rod 40 (the valve body portion 43) upward

as viewed in the drawing. Therefore, the movable iron core 64 and the rod 40 integrally move vertically.

A coil 67 is wound about the fixed iron core 62 and the movable iron core 64. The coil 67 receives drive signals based on commands that are sent from an air conditioner ECU (not shown) according to parameters such as thermal load. The coil 67 generates an electromagnetic attraction force (electromagnetic urging force) between the movable iron core 64 and the fixed iron core 62. The magnitude of the generated force corresponds to the value of the supplied current per unit time.

A target value sought in a control of the two-point pressure difference, or a target pressure difference as an operation reference, is determined by the amount of current supplied to the coil 67. The pressure sensing member 54 automatically determines the axial position of the rod 40 (the valve body portion 43) according to the two-point pressure difference such that the target pressure difference is maintained.

For example, if the flow rate of the refrigerant in the refrigerant circuit is decreased due to a decrease in the rotation speed of the engine E, that is, if the two-point pressure difference is decreased from the target pressure difference, the downward force applied to the rod 40 by the pressure sensing member 54 based on the two-point pressure difference decreases. If the upward electromagnetic force of the solenoid 60 is not changed from the value at the time, the upward and downward forces acting on the rod 40 are not balanced. Thus, the rod 40 (the valve body portion 43) moves upward to decrease the opening degree of the valve hole 47a, which lowers the pressure in the crank chamber 15. Accordingly, the inclination angle of the swash plate 18 is

increased, and the displacement of the compressor C is increased. The increase in the displacement of the compressor C increases the flow rate of refrigerant in the refrigerant circuit. This increases the two-point pressure difference in the refrigerant circuit so that the pressure difference seeks the target pressure difference.

If the flow rate of the refrigerant in the refrigerant circuit is increased due to an increase in the rotation speed of the engine E, that is, if the two-point pressure difference is increased from the target pressure difference, the downward force applied to the rod 40 by the pressure sensing member 54 based on the two-point pressure difference increases. If the upward electromagnetic force of the solenoid 60 is not changed from the value at the time, the upward and downward forces acting on the rod 40 are not balanced. Thus, the rod 40 (the valve body portion 43) moves downward to increase the opening degree of the valve hole 47a, which raises the pressure in the crank chamber 15. Accordingly, the inclination angle of the swash plate 18 is decreased, and the displacement of the compressor C is decreased. The decrease in the displacement of the compressor C decreases the flow rate of refrigerant in the refrigerant circuit. This decreases the two-point pressure difference in the refrigerant circuit so that the pressure difference seeks the target pressure difference.

The target pressure difference can be externally changed by adjusting the amount of electricity supplied to the coil 67. For example, if the amount of electricity supplied to the coil 67 is increased, the upward electromagnetic force applied to the rod 40 by the solenoid 60 is increased. In this case, if the force of the pressure sensing member 54 based on the two-point pressure difference is not changed, the upward force and the downward force acting on the rod 40 are not balanced. Accordingly, the rod 40 (the valve body portion 43) is moved

upward to decrease the opening degree of the valve hole 47a, and the displacement of the compressor C is increased. As a result, the flow rate of refrigerant in the refrigerant circuit increases. This increases the two-point pressure difference in the refrigerant circuit. That is, increasing the amount of electricity supplied to the coil 67 increases the target pressure difference.

If the amount of electricity supplied to the coil 67 is decreased, the upward electromagnetic force applied to the rod 40 by the solenoid 60 is decreased. In this case, if the force of the pressure sensing member 54 based on the two-point pressure difference is not changed, the upward force and the downward force acting on the rod 40 are not balanced. Accordingly, the rod 40 (the valve body portion 43) is moved downward to increase the opening degree of the valve hole 47a, and the displacement of the compressor C is decreased. As a result, the flow rate of refrigerant in the refrigerant circuit decreases. This decreases the two-point pressure difference in the refrigerant circuit. That is, decreasing the amount of electricity supplied to the coil 67 decreases the target pressure difference.

The present embodiment has the following advantages.

(1) In the control valve CV1, the separation portion 41 of the rod 40 disconnects the valve chamber 46 from the second chamber 56 through the through hole 47. Therefore, the pressure of the second chamber 56 is not directly affected by changes in the opening degree of the valve body portion 43. This prevents the pressure in the second chamber 56 from being fluctuated by changes in the valve opening degree. Thus, the pressure sensing member 54 accurately determines the position of the rod 40 (the valve body portion 43) without being affected by changes in the valve opening degree. Accordingly, the pressure displacement is accurately controlled.

The second chamber 56 of the control valve CV1 and the valve hole 47a, which is adjacent to the second chamber 56 with the separation portion 41 in between, are both connected to the second pressure zone PdL. This configuration prevents the pressure of the valve hole 47a and the pressure of the second chamber 56 from differing from each other. Therefore, the entry of foreign particles to the sliding portions of the through hole 47 and the rod 40 (the separation portion 41) due to the pressure difference between the valve hole 47a and the second chamber 56 is prevented. The rod 40 is therefore prevented from malfunctioning due to foreign particles.

As described above, this embodiment prevents the rod 40 from malfunctioning and also prevents the controllability of the compressor displacement from deteriorating.

(2) The fixed restrictor 34 is provided in the discharge pressure zone Pd. The section upstream of the fixed restrictor 34 is the first pressure zone PdH, and the section downstream of the fixed restrictor 34 is the second pressure zone PdL. The two-point pressure difference, which is the pressure difference between the section upstream of the fixed restrictor 34 and the section downstream of the fixed restrictor 34, is greater than a pressure difference caused by the passage resistance in a passage having no restrictor. Therefore, the control valve CV1, which operates by detecting the two-point pressure difference, accurately reflects changes in the refrigerant flow rate when determining the position of the rod 40 (the valve body portion 43). The control valve CV1 thus accurately controls the displacement of the compressor C.

Although the pressure in the section upstream of the fixed restrictor 34 and the pressure in the section downstream of the fixed restrictor 34 are pressures in the discharge

pressure zone Pd, these two pressures upstream and downstream of the restrictor 34 are greatly different from each other in some cases. Therefore, connecting the second chamber 56 and the valve hole 47a, which are adjacent to each other with the separation portion 41 in between, to the second pressure zone PdL, or to the section downstream of the fixed restrictor 34, is particularly advantageous to provide the above advantage (prevention of malfunction of the rod 40).

(3) The valve housing 45 of the control valve CV1 is inserted in the accommodation recess 35 formed in the rear housing member 14. The second chamber 56 is connected to the valve hole 47a through the first connecting chamber 50a, which is a space defined between the inner surface 35a of the accommodation recess 35 and the outer surface 45d of the valve housing 45. Therefore, only one passage is required for connecting the second pressure zone PdL with the first connecting chamber 50a. Thus, for example, compared to a case in which the second chamber 56 and the valve hole 47a are each connected to the second pressure zone PdL through an independent passage, respectively, the structure is simplified.

The first connecting chamber 50a has a relatively large volume. This lessens the influences of pressure fluctuations caused by changes in the valve opening degree of the valve hole 47a to the second chamber 56. Further, the second chamber 56 is connected to the valve hole 47a through the first connecting chamber 50a located outside of the valve housing 45. This structure extends the length of the passage between the second chamber 56 and the valve hole 47a. This configuration reliably prevents the pressure of the second chamber 56 from being directly influenced by changes in the valve opening degree.

(4) The control valve CV1 has the solenoid 60, which is an electromagnetic actuator. As stated in the prior art section, in a control valve having an electromagnetic actuator, adopting a structure that completely opens the entire through hole 47 as a part of the supply passage 30 worsens the controllability of the displacement. Thus, in the control valve CV1 having the solenoid 60, blocking the connection between the valve chamber 46 and the second chamber 56 through the through hole 47 with the separation portion 41 of the rod 40 is particularly advantageous to improve the controllability of the displacement.

A second embodiment of the present invention will now be described. As shown in Fig. 3, a control valve CV2 of the second embodiment is the same as the control valve CV1 of the first embodiment except for that the fourth port 58 is omitted. The second chamber 56 is connected to the second port 52 through a hole 71 formed in the separation wall 49. Therefore, the pressure of the second pressure zone PdL is introduced to the second chamber 56 through the second port 52 and the hole 71. That is, the second port 52 and the hole 71 form a connecting passage. The connecting passage (the second port 52 and the hole 71) connects the second chamber 56 with the valve hole 47a within the valve housing 45.

The second embodiment provides the same advantages as (1), (2) and (4) of the first embodiment. Other than these advantages, the second embodiment has the following advantages. That is, the second chamber 56 and the valve hole 47a are connected to each other within the valve housing 45 through the connecting passage (the second port 52 and the hole 71). Thus, only one passage, which is connected to the valve hole 47a, is required for connecting the second pressure zone PdL to the control valve CV2. Thus, for example, compared to a case in which the second chamber 56 and the

valve hole 47a are each connected to the second pressure zone PdL through an independent passage, respectively, the structure is simplified.

For example, compared to the first embodiment, in which the second chamber 56 and the valve hole 47a are connected to each other through the space defined by the inner surface 35a of the accommodation recess 35 and the outer surface 45d of the valve housing 45, that is the first connecting chamber 50a, no great space needs to be created between the inner surface 35a of the accommodation recess 35 and the outer surface 45d of the valve housing 45. Therefore, the inner surface 35a of the accommodation recess 35 are brought into close contact with the outer surface 45d of the valve housing 45 in a relatively large area. This permits the rear housing member 14 of the compressor C to stably support the control valve CV2.

A third embodiment of the present invention will now be described. As shown in Fig. 4, a control valve CV3 of the third embodiment is the same as the control valve CV1 of the first embodiment except for that the opening degree of the bleed passage 29, not the opening degree of the supply passage 30, is adjusted. The supply passage 30 is always open. The control valve CV3 adjusts the opening degree of the bleed passage 29, thereby changing the flow rate of refrigerant gas conducted to the suction chamber 23 from the crank chamber 15 through the bleed passage 29. As a result, the pressure of the crank chamber 15 is adjusted, and the displacement of the compressor C is controlled, accordingly.

Unlike the control valve CV1 of the first embodiment, the first chamber 55 and the second chamber 56 forming the pressure sensing chamber 48 of the control valve CV3 according to the third embodiment are connected to a suction pressure

zone Ps of the refrigerant circuit.

A section of the refrigerant circuit from the outlet of the evaporator 33 to the suction chamber 23 of the compressor forms the suction pressure zone Ps. A fixed restrictor 91 is provided in the suction pressure zone Ps. The suction pressure zone Ps includes a first pressure zone PsH and a second pressure zone PsL. The first pressure zone PsH is located upstream of the fixed restrictor 91, or at the side corresponding to the evaporator 33. The second pressure zone PsL is located downstream of the fixed restrictor 91, or at the side corresponding to the suction chamber 23. The pressure of the first pressure zone PsH is higher than the pressure of the second pressure zone PsL. The pressure of the first pressure zone PsH is introduced to the first chamber 55 through a pressure introduction passage 92 formed in the rear housing member 14 and the third port 57. The bleed passage 29 includes an upstream section 29a upstream of the accommodation recess 35 and a downstream section 29b downstream of the accommodation recess 35. The suction chamber 23 forms a part of the second pressure zone PsL. The pressure of the suction chamber 23 is introduced to the second chamber 56 through the downstream section 29b, the first connecting chamber 50a, and the fourth port 58.

An inner connecting chamber 94 and a valve accommodating hole 95 are defined in the upper portion 45b of the control valve CV3. The valve accommodating hole 95 functions as a valve chamber and a through hole. The inner connecting chamber 94 and the valve accommodating hole 95 are connected to each other by a connecting passage 96 that has a smaller cross-sectional area than the valve accommodating hole 95. The rod 40 is movably provided in the inner connecting chamber 94, the connecting passage 96, and the valve accommodating hole 95. The separation portion 41 of the rod 40 is slidably

inserted in the valve accommodating hole 95 and separates the valve accommodating hole 95 from the pressure sensing chamber 48. The diameter of the coupler portion 42 of the rod 40 is less than that of the connecting passage 96 and permits the inner connecting chamber 94 to communicate with the valve accommodating hole 95.

In this embodiment, the valve body portion 43 forms part of the separation portion 41. The valve body portion 43 is located in the valve accommodating hole 95. A step defined between the valve accommodating hole 95 and the connecting passage 96 forms the valve seat 53. The connecting passage 96 functions as a valve hole.

The inner connecting chamber 94 is connected to the crank chamber 15 through the first port 51, the second connecting chamber 50b, and the upstream section 29a of the bleed passage 29. Part of the valve accommodating hole 95 that is closer to the inner connecting chamber 94 will be referred to a valve body accommodating portion 95a. The valve body accommodating portion 95a is adjacent to second chamber 56 with the separation portion 41 in between. The valve body accommodating portion 95a is connected to the suction chamber 23 through the second port 52, the first connecting chamber 50a, and the downstream section 29b of the bleed passage 29. That is, the second chamber 56 and the valve body accommodating portion 95a of the valve accommodating hole 95 are both connected to a common pressure zone in the refrigerant circuit, or to the second pressure zone PsL.

As the flow rate of refrigerant in the refrigerant circuit increases, the difference between a section upstream of the fixed restrictor 91 and a section downstream of the fixed restrictor 91, or the two-point pressure difference, is increased. That is, the two-point pressure difference

corresponds to the pressure loss between the section upstream of the fixed restrictor 91 and the section downstream of the fixed restrictor 34, and positively correlates with the flow rate in the refrigerant circuit. Therefore, the control valve CV3 of this embodiment operates in the same manner as the control valve CV1 of the first embodiment. That is, the control valve CV3 adjusts the opening degree of the bleed passage 29 such that the displacement of the compressor is changed to cancel fluctuations of the refrigerant flow rate.

The third embodiment provides the same advantages as (1) to (4) of the first embodiment.

A fourth embodiment of the present invention will now be described. As shown in Fig. 5, a control valve CV4 of the fourth embodiment is the same as the control valve CV1 of the first embodiment except for that the solenoid 60 is omitted. Further, the control valve CV4 controls the opening degree of the bleed passage 29, but not the opening degree of the supply passage 30.

That is, in the fourth embodiment, the valve chamber 46 is a part of the bleed passage 29 that is located in the control valve CV4. The valve chamber 46 accommodates a valve body 75 attached to the rod 40. The valve body 75 can be displaced in the valve chamber 46. The pressure sensing member 54 and the valve body 75 are coupled to each other with the rod 40. A valve hole 76, which forms part of the bleed passage 29, is spaced apart from the through hole 47. Specifically, the valve hole 76 is connected to the valve chamber 46 at a part opposite from the part corresponding to the through hole 47 with respect to the valve body 75.

The second chamber 56 of the control valve CV4 is connected to the suction chamber 23 through a port 80 formed

in the valve housing 45, and a pressure introducing passage 77 formed in the rear housing member 14. The first chamber 55 is either exposed to the atmosphere or is in a vacuum. That is, the internal pressure of the first chamber 55 is maintained to a substantially constant reference pressure. The valve chamber 46 is connected to the suction chamber 23 through a port 81 formed in the valve housing 45, and the downstream section 29b of the bleed passage 29. The valve hole 76 is connected to the crank chamber 15 through a port 82 formed in the valve housing 45, and the upstream section 29a of the bleed passage 29. That is, the second chamber 56 and the valve chamber 46, which are adjacent to each other with the separation portion 41 of the rod 40 in between, are both exposed to the pressure of the suction chamber 23, which forms part of the suction pressure zone.

In other words, in the fourth embodiment, the valve chamber 46 is the adjacent zone, which is adjacent to the second chamber 56 with the separation portion 41 in between. The second chamber 56 and the valve hole 47a are both connected to a common pressure zone in the refrigerant circuit, or to the suction chamber 23.

The downstream section 29b of the bleed passage 29 and the pressure introducing passage 77 may be separately formed or have a common section. As in the first embodiment, the space 50 may be defined between the outer surface 45d of the valve housing 45 and the inner surface of the accommodation recess 35, and the valve chamber 46 may be connected to the second chamber 56 through the space 50 (see Fig 2). Alternatively, as in the second embodiment, the hole 71 may be formed in the separation wall 49, and the valve chamber 46 and the second chamber 56 may be connected to each other through the hole 71 within the valve housing 45 (see Fig. 3).

In the compressor of fourth embodiment, highly pressurized discharge refrigerant gas is supplied from the discharge chamber 24 to the crank chamber 15 through the supply passage 30. On the other hand, to maintain the pressure of the suction chamber 23 at a constant level, the pressure sensing member 54 of the control valve CV4 is displaced in accordance with the difference between the pressure of the suction chamber 23, which is introduced to the second chamber 56 through the pressure introducing passage 77, and the reference pressure in the first chamber 55 to determine the axial position of the valve body 75. Accordingly, the opening degree of the valve hole 76 is adjusted. The control valve CV4 adjusts the opening degree of the bleed passage 29, thereby changing the flow rate of refrigerant gas conducted to the suction chamber 23 from the crank chamber 15 through the bleed passage 29. As a result, the pressure of the crank chamber 15 is adjusted, and the displacement of the compressor C is controlled, accordingly.

For example, when the temperature of the passenger compartment increases, the cooling load increases. This increases the pressure in the suction chamber 23. Accordingly, the pressure difference between the second chamber 56 and the first chamber 55 in the control valve CV4 is increased. Therefore, the pressure sensing member 54 is displaced downward as viewed in the drawing against the reference pressure of the first chamber 55 and the force of the urging spring 78, which is located in the pressure sensing member 54 and urges the valve body 75 toward the valve seat 53 through the rod 40. Accordingly, the valve body 75 is displaced to increase the valve opening, and the pressure in the crank chamber 15 is lowered. Accordingly the displacement of the compressor C is increased. The increase in the compressor displacement lowers the suction pressure in the suction chamber 23.

When the temperature of the passenger compartment decreases, the cooling load decreases. This decreases the suction pressure in the suction chamber 23. Accordingly, the pressure difference between the second chamber 56 and the first chamber 55 in the control valve CV4 is decreased. Therefore, the pressure sensing member 54 is displaced upward as viewed in the drawing by the reference pressure of the first chamber 55 and the force of the urging spring 78. Accordingly, the valve body 75 is displaced to decrease the valve opening, and the pressure in the crank chamber 15 is raised. Accordingly the displacement of the compressor C is decreased. The decrease in the compressor displacement raises the suction pressure in the suction chamber 23.

The fourth embodiment provides the same advantage as (1) of the first embodiment.

The present invention may be embodied in the following forms without departing from the spirit or scope of the invention.

In the first to third embodiments, the solenoid 60 may be omitted from the control valves CV1 to CV3 so that the control valves CV1 to CV3 are simple pressure sensing valves that are not capable of being externally controlled.

In the fourth embodiment, a solenoid may be added to the control valve CV4, so that the control valve CV4 is a pressure sensing valve that is capable of being externally controlled. In this case, the pressure sensing member 54 of the control valve CV4 is automatically displaced according to fluctuations in the suction pressure to determine the axial position of the valve body 75, such that a target value of the suction pressure, which is determined by the amount of electricity

supplied to the solenoid, is maintained. That is, the pressure sensing member 54 is displaced such that the target suction pressure as the operation reference is maintained. The target suction pressure can be externally changed by adjusting the amount of electricity supplied to the solenoid.

In the control valves CV1 and CV2 of the first and second embodiments, the first chamber 55 is exposed to the pressure of the first pressure zone PdH, which is a higher pressure section of the discharge pressure zone Pd, and the second chamber 56 and the valve hole 47a are each exposed to the pressure of the second pressure zone PdL, which is a lower pressure section of the discharge pressure zone Pd. In the control valve CV3 of the third embodiment, the first chamber 55 is exposed to the pressure of the first pressure zone PsH, which is a higher pressure section of the suction pressure zone Ps, and the second chamber 56 and the valve body accommodating portion 95a, which is a valve chamber, are each exposed to the pressure of the second pressure zone PsL, which is a lower pressure section of the suction pressure zone Ps. That is, in the first to third embodiments, the pressure of the first chamber 55 is higher than those of the second chamber 56 and the adjacent zone (the valve hole 47a and the valve body accommodating portion 95a). However, the pressure of the first chamber 55 may be lower than those of the second chamber and the adjacent zone. That is, the first chamber 55 of the control valves may be exposed to the pressure of the second pressure zone, and the second chamber 56 and the adjacent zone may be exposed to the pressure of the first pressure zone.

In the control valves CV1 to CV3 of the first to third embodiments, setting the pressure of the first chamber higher than the pressure of the second chamber reverses the direction of displacement of the pressure sensing member 54 based on the

pressure difference between the first chamber 55 and the second chamber 56. Therefore, in the modifications of the first and second embodiments, the arrangement of the valve hole and the valve chamber with respect to the pressure sensing chamber 48 needs to be inverted so that an increase in the pressure difference between the first and second chambers 55, 56 displaces the valve body portion 43 to increase the valve opening degree. That is, the second chamber 56 and the valve chamber 46 are arranged to be adjacent to each other with the separation portion 41 in between. In the modification of the third embodiment, the arrangement of the valve hole and the valve chamber with respect to the pressure sensing chamber 48 needs to be inverted so that an increase in the pressure difference between the first and second chambers 55, 56 displaces the valve body to decrease the valve opening degree. That is, the second chamber 56 and the valve hole are arranged to be adjacent to each other with the separation portion 41 in between.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.